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Assessing the impact of conventional urea and Nano-urea on soil microbial biomass and enzyme activities

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Abstract

Optimizing fertilizer application is critical for maintaining soil health, promoting crop productivity, and minimizing environmental degradation. The advent of nano-fertilizers offers new opportunities for efficient nutrient management. This study evaluated the effects of conventional urea and nano-urea on soil biological properties and enzyme activities in tomato cultivation. Significant differences were observed in soil pH among treatments, with the highest (7.51) pH recorded in T₁₂ (50% RDN as basal dose + nano-urea (2 ml L⁻¹) at 30 and 45 DAT). However, organic carbon content and soil microbial biomass remained unaffected. Notably, nitrogenous fertilizer application significantly influenced soil enzyme activities, with T₄ (100% RDN with nano-urea at 30 and 45 DAT) exhibiting the highest (20.42 µg TPF g⁻¹ soil 24hr⁻¹) dehydrogenase activity, and T₁ where, 100% RDN was applied only through the conventional urea showed the highest (5.96 and µg PNP g⁻¹ h⁻¹) acid phosphatase activity. These findings provide insights into optimizing fertilizer management for improved soil health and enzyme activity.

Keywords: Urea, soil quality, soil microbial biomass, dehydrogenase, acid phosphatase

Introduction

Soil is fundamental to life on land, and its degradation can lead to severe consequences, including reduced fertility, erosion, water pollution, and loss of biodiversity. To evaluate soil health, it's crucial to monitor changes in biological properties, which are highly responsive to environmental changes. Soil microbial indicators are the valuable tool for diagnosing soil health, which are very sensitive and respond quickly to environmental alterations (Wolińska and Stepniewska, 2012) [30]. The connection between soil enzymes and microorganisms highlights the importance of maintaining a balanced ecosystem to support soil life processes. Soil microbial biomass (SMB) has been defined as the 'eye of a needle' through which all soil organic matter (SOM) needs to pass (Rattan 2023) [20]. It plays a key role in SOM decomposition, soil structuring and nutrient cycling thus has been identified as an important component for maintaining soil quality (Mganga *et al.*, 2024) [18]. Soil dehydrogenase activity (DHA) serves as a key indicator of soil quality and microbial activity (Xie *et al.*, 2009; Tejada *et al.*, 2010) [10, 31, 27]. Unlike other enzymes that can arise in an extracellular condition, dehydrogenase activity exclusively occurs within living cells, making it one of the best indicators of microbial activity in soil (Cooper and Warman 1997) [8, 10]. Acid phosphatase also a crucial indicator of soil health, measuring the enzymatic breakdown of organic phosphorus into plant-available forms (Turner *et al.*, 2005) [28], and is the most commonly assessed phosphatase activity in soil studies (Margalef *et al.*, 2017) [16].

The application of organic and inorganic fertilizers can enhance nutrient availability to the crop (Macci *et al.*, 2012) [33], thereby promoting the plant growth through the provision of essential nutrients, Primarily, nitrogen (N), phosphorus (P), and potassium (K) (Chu *et al.*, 2007) [34]. Among them nitrogen is the most essential nutrient required for crop plants as it is a key constituent of amino acids, enzymes, photosynthetic pigments and energy transfer compounds, thus it plays an important role in vegetative growth of the crops (Fathi., 2022) [12]. Excessive and improper usage of nitrogenous fertilizer causes problems on human and environment (Ahmed *et al.* 2017) [11].

Nano urea is the alternative to conventional urea fertilizer with slow and controlled release of nutrients (Lohar., 2023)^[15] which provides new interdisciplinary venture into agriculture and food sciences by converging science and engineering. Understanding the effects of urea and nano urea on soil biological properties and soil enzymes is vital for sustainable agriculture, as it reflects the overall functioning of the soil ecosystem. In view of this, the present study was conducted. To evaluate the impact of conventional urea and nano-urea on soil microbial biomass and soil enzymes.

Materials and Methods

The study was conducted at the College of Horticulture, Bagalkot (16°10' N latitude, 74°42' E longitude, 542m elevation) during 2022-2023. The region situated in northern dry agro-climatic zone of Karnataka (Zone-3). The average annual rainfall of the experimental site is 548mm and temperatures is 23.01 °C and the soil type was red sandy loam. During the experiment, the total rainfall was 49.9 mm, with mean morning and afternoon relative humidity of 77.64% and 28.75%, respectively and the maximum and minimum temperatures were 35.71 °C and 18.57 °C, respectively. the experiment was laid out in a Randomized Complete Block Design (RCBD) with 12 treatments replicated thrice, using Tomato (Hybrid-Abhilash) plants spaced at 90 x 45 cm under irrigated conditions during the spring-summer season.

Experimental details

T₁ (100% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT
 T₂ (100% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT + 25% urea at 45 DAT
 T₃ (100% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L⁻¹) at 45 DAT
 T₄ (100% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 and 45 DAT
 T₅ (75% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT
 T₆ (75% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT + 25% urea at 45 DAT
 T₇ (75% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L⁻¹) at 45 DAT
 T₈ (75% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 and 45 DAT
 T₉ (50% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT
 T₁₀ (50% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT + 25% urea at 45 DAT
 T₁₁ (50% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L⁻¹) at 45 DAT
 T₁₂ (50% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 and 45 DAT

RDN: recommended dose of nitrogen, **DAT:** Days after transplantation

Fertilizer application

The fertilizer recommendation for tomato as per package of practice (POP) of University of Horticultural Sciences Bagalkot, was followed (38 tons FYM and 250:250:250 Kg N: P₂O₅: K₂O per hectare) and was applied in accordance with the treatment details. Soil application of urea, single

super phosphate (SSP), muriate of potash (MOP) and foliar application of nano urea (IFFCO nano urea was brought from the local market) was followed as per the schedule. Half dose of nitrogen together with the full dose of phosphorous and potassium was supplemented as basal dose at 2 days after transplanting (DAT) and top dressing of urea and nano urea (2 ml L⁻¹) was followed at 30 and 45 days after transplanting.

Soil sample collection and analysis

After the harvest of the crop, soil samples were collected from a depth of 0 to 15 cm and a composite sample was made using the quartering technique. The collected soil samples were shade dried, and passed through 2 mm sieve (Klute, 1986)^[14]. These samples were analysed for different parameters by adopting appropriate protocols.

Soil pH was determined potentiometrically in a 1:2.5 soil-water suspension as suggested by Jackson (1973)^[13] and organic carbon (OC) content was assessed using the chromic acid wet digestion method (Walkley and Black, 1934). Soil microbial biomass (SMB) was estimated by fumigation-extraction method as detailed by Carter (1991)^[5]. Dehydrogenase activity in the soil samples was determined by following the procedure as described by Casida *et al.* (1964)^[6]. Phosphatase activity of soil samples was determined by measuring p-nitrophenol content (Tabatabai and Berner, 1969)^[26].

Statistical analysis

The data in respect of all the parameters were tabulated and subjected to the statistical analysis (ANOVA) by adopting Randomized Complete Block Design and results were tested at 5 percent level of significance using Fischer's method of analysis of variance as suggested by Panse and Sukhatme (1967)^[37]. Critical difference at 5 percent was worked out whenever 'F' test was significant.

Results and Discussions

Soil microbial biomass and enzyme activity are crucial indicators of soil health, influencing nutrient cycling and ecosystem functioning. The application of nitrogenous fertilizers showed a significant impact on the soil biological properties.

The data pertaining to soil pH after the harvest of the crop presented in figure-1, varied significantly among treatments, with values ranging from 7.51 to 7.24, indicating a decrease from the initial pH of 7.62 across all treatments. Application of 50% RDN: 50% of urea as basal dose + foliar application of nano urea (2 ml L⁻¹) at 30 and 45 DAT (T₁₂) exhibited the higher (7.51) soil pH. Whereas, the application of 100% RDN: 50% of urea as basal dose and another 50% of urea in two equal split at 30 and 45 DAT (T₁) exhibited the lower (7.24) soil pH. The Soil properties showed minimal response to nano-urea treatments, but application of conventional urea (100% RDN) lowered the soil pH (Subramani *et al.*, 2023)^[25]. Urea applied to the soil reacts with water and the soil enzyme urease, and is rapidly converted to ammonium leads to urea hydrolysis. In this reaction, hydrogen ions (H⁺) are consumed, causing the soil pH near the fertilizer to rise. But acidity is again produced when ammonium-N undergoes nitrification (Anon., 2022)^[35].

Regarding the amount of organic carbon in the soil after application of treatments, does not show any significant

difference among the treatments. The results indicate that the urea and nano urea treatments had little effect on soil characteristics, which is consistent with the findings of Subramani *et al.* (2023) [25]. The application of urea and nano urea does not significantly alter the SOC content, according to Sikka *et al.* (2024) [24].

Perusal of data on soil microbial biomass also not recorded any significant difference among the treatments. Urea fertilization did not contribute to any notable short-term impact on the soil biological properties. Despite this, the soil microbial biomass decreased when a larger quantity of conventional urea was applied to the treatments. The findings were in line with those of Dalal (1998) [9]. In two long-term field studies conducted in Iowa, Moore *et al.* (2000) [19] found that urea fertilisation (180 kg N ha⁻¹ each rotation) had no discernible impact on the microbial biomass. The microbial biomass in clay loam and fine sandy loam soils was not significantly affected by urea application (50 kg N ha⁻¹), according to Banerjee *et al.* (1999) [4]. In two Japanese upland farms, Zaman *et al.* (2002) also found that applying organic N sources-sewage sludge compost with sawdust or rice husk-instead of chemical fertiliser enhanced soil microbial biomass. Following two years of application, N fertilisation had no discernible impact on soil microbial biomass at depths of 0-5 cm or 5-10 cm (Chu *et al.* 2005) [7]. Whereas, the application of nitrogenous fertilizers to the soil showed a significant difference in soil enzyme activity *viz.*, dehydrogenase and acid phosphatase.

Application of 100% RDN (50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT and 45 DAT) in T₄ showed highest (20.42 µg TPF g⁻¹ soil 24hr⁻¹) dehydrogenase activity. Followed by, application of 75% RDN (50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT and 45 DAT) in T₈, also showed significantly higher (20.31 µg TPF g⁻¹ soil 24hr⁻¹) dehydrogenase activity. This may be due to the application of less quantity of inorganic fertilizers to the soil (Saritha and Tollamadugu, 2019) [21]. a strong negative impact of intensive fertilizer on DHA was demonstrated by Moeskops *et al.*, 2010 [36]. Soil pH is a key predictor of soil dehydrogenase activity which affects its activity by altering the enzyme's structure, its active site, and substrate binding, thereby influencing reaction rate (Shuler & Kargi, 2010) [23]. Acid phosphatase activity recorded the highest (5.96 and 5.73 µg PNP g⁻¹ h⁻¹, respectively) value with the application of 100% RDN: 50% as basal dose of urea and another 50% in two equal splits of urea at 30 and 45 DAT (T₁) and application of 75% RDN: 50% as basal dose of urea and another 50% in two equal splits of urea at 30 and 45 DAT (T₅). This might be due to the fact that, in all the soil samples enriched with urea, pH becomes reduced and the activity of acid phosphatase was found to be significantly higher (Shetty *et al.*, 2019) [22]. The rate and timing of N fertilization had little impact on the activity of acid phosphatase (Davies *et al.* 2022) [38]. N application has been reported to be directly linked to phosphatase activity in soils (Ajwa *et al.* 1999, Marklein and Houlton, 2012) [2, 17]. Phosphatase activity has been shown to be correlated with organic C, and organic C could have an important role in protecting and maintaining acid phosphatase activity (Deng and Tabatabai, 1997) [1].

Conclusion

The study highlights the impacts of conventional urea and nano-urea on soil biological properties. Since nano-urea was

applied via foliar spray, it may not affected soil microbial biomass or enzyme activity. In contrast, conventional urea application to the soil significantly influenced soil enzyme activity by altering soil pH. Notably, the combination of conventional urea and nano-urea (100% RDN: 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT and 45 DAT) maintained better soil quality as per the study. Further studies are essential to elucidate the complex interactions between fertilizers, soil biology, and ecosystem functioning.

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